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DATA CONCERNING THE FORMATION OF NEW AFFERENT PATHWAYS OF THE BLADDER AND LARGE INTESTINE

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Chair of Human Anatomy (Head - Prof. D. M. Golub) of Minsk Medical Institute and the Laboratory of Morphology of the Institute of Physiology of the Academy of Sciences BSSR.
Submitted to the Editorial Board 11 April 1959.

It has been known for a long time that traumas of the spinal cord and, especially, a complete severance lead to grave impairments of the function of the internal organs and the lower extremities. The urinary bladder suffers gravely (I. S. Babshin, 1954; A. N. Bakulev, 1944; A. V. Bondarchuk, 1942; A. I. Vasil'yev, 1942; A. P. Frumkin, 1944; V. N. Shamov, 1944, etc.). The problem of restoration of the function of the urinary bladder and other organs of the small pelvis also continues to remain urgent (Ye. F. Vlasova, 1958; M. R. Kasatkin, 1958, etc.).

Since in traumas of the spinal cord the innervation apparatus and the conducting pathways of the organs of the small pelvis undoubtedly suffer and the available collateral pathways are not always capable of compensating substantially for the missing function, we have undertaken to study the formation of new collateral innervation pathways.

Our investigations were developed in two directions:

We could attempt to restore the innervation of the urinary bladder by forming an anastomosis of its nerves with the voluntary and involuntary nerves located at higher levels. Such an approach is justified in the already known works of native and foreign investigators in the creation of heterogenous neural anastomoses (Fluran, 1828; Rava, 1884; N. A. Mislavskiy, 1902; Buke -- Voyeke, 1913; B. I. Lavrent'yev, 1934; M. A. Baron, 1935; P. K. Anokhin, 1935, etc.).

On the other hand, a possibility presented itself

of the formation of new innervation pathways of the organs of the lesser pelvis by means of the nerves of those organs situated at higher levels; this technique may be especially applicable in suturing the organs together. The rationale of this approach is based on the fact that there are data in the available literature on the presence of neural elements in the commissures between organs. As is known, the presence of neural fibers in the commissures between the organs of the abdominal cavity was first demonstrated by S. S. Girgolav (1923). Later, the M. A. Baron Laboratory (V. N. Blumkin, 1949, 1954; Ya. Ye. Kheson, 1949, 1956) developed in detail the problem of commissure morphology in the abdominal cavity and the structure of their innervating apparatus.

V. N. Blumkin observed the growth of neural fibers not only into the commissure but into the united organ as well; with this technique, newly formed nerve endings have been elicited. Ya. Ye. Khesin demonstrated that upon suturing the initial section of the large intestine to the urinary bladder, new motor paths originate. These authors conducted their investigations to study the mechanism of commissure pains, as well as to explain certain forms of functional ileus. However, in these very interesting works no question was raised concerning the possibility of compensating the function of the urinary bladder and other pelvic organs by means of new pathways appearing during the formation of commissures.

On the basis of the above, we conducted several series of experiments.

In the first series (eight test dogs plus two controls) a section of the ileac wall was satured to the posterior wall of the urinary bladder. The serous membrane was incised or entirely removed in the sewed sections. In all test cases a commissure emerged between the ileac intestine and the urinary bladder; no side phenomena and almost no other commissures were noted. At various periods following the operation (60 days in two cases, 75, 91, 142, 150, 164, and 165 days in the remaining six, precise experiments were carried out in observing the changes of respiration and blood pressure upon distention of the urinary bladder. The following results were obtained.

Within 60 days after the operation (Experiment 3), a physiological test was made which showed that distention of the urinary bladder with 100 to 200 ml. of air for a period of one minute within the abdominal cavity and outside of it causes increase of blood pressure and deepening of respiration (Fig. 1, A). Stimulation of the urinary

bladder, which had remained connected with the wall of the small intestine via a commissure only, also leads to changes in blood pressure and respiration though to a less marked degree (Fig. 2, B). Under these conditions, movements of the head and lower extremities of the dog were observed. Further examination enabled us to discern a well expressed commissure containing a large number of newly formed blood vessels. Large bundles of nerve fibers extend along the route of the blood vessels. Numerous nerve fibers branch out in the commissure and form nets in which accumulations of neurons are encountered. Neural nodes of various sizes are observed within the body of the commissure. They contain large cells of oval or pear-shaped form, with the nuclei situated away from the center in the latter. Long dendrites protrude from the cells and enter into the composition of the neural bundles of the commissure. There are pronounced pericellular apparatus in some cells. Bundles containing thin and, occasionally, thick neural fibers pass through the nodes. Around the nodes are tortuous blood vessels. Parallel with mature neural cells, neuroblasts are seen in the nodes.

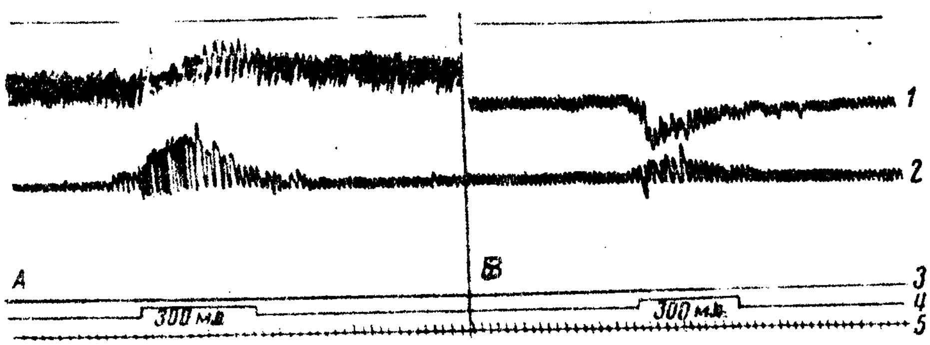

Fig. 1
Effect of the distention of the urinary bladder by a balloon on the blood pressure in the carotid artery and on respiration. Experiment 3. A -- distention of the urinary bladder in the control animal. B -- Distention of the bladder after severing all connections except the newly formed one. 1 - blood pressure in the carotid artery. 2 - respiration. 3 - zero line of blood pressure. 4 - indication of the bladder distention. 5 - marking of time - five seconds.

Subsequent observations confirmed the above data and permitted a more complete characterization of the neural and vascular elements in the commissure. In the latter one could note (Experiment No. 5) a large number of newly formed blood vessels in the form of a net containing well formed small neural stems and nemerous neural fibers (Fig. 2a). The nerves of the urinary bladder are the source of these fibers. From the bladder neural bundles grow into the commissure along a tortuous path (Fig. 2b). These bundles branch out, their fibers intertwined, and cause the typical picture observed in neuromas (Fig. 2c). Simultaneously in the commissure are elicited neural nodes consisting of multipolar and bipolar cells which manifest the pericellular apparatus. On Fig. 2d a node is shown situated in the commissure; two bundles of neural fibers pass through it. The stronger one consists of fine neural fibers containing some fibers which terminate in bulb-like distentions. Synaptic endings are present on the cells of the nodes.

The morphological observations in this case also coincide with the physiological ones. During the distention of the urinary bladder, all connections are eliminated, with the exception of the commissure with the ileac. Administration of 300 ml. air for one minute causes a distinct effect on the respiration and blood pressure. Respiration becomes deeper and more frequent; the blood pressure rises.

In certain cases muscular bundles from the walls of the urinary bladder are drawn into the composition of the commissure. It is most clearly noted in experiment 13. One can observe here within the composition of one of these bundles a large number of neural fibers which run longitudinally (Fig. 3a). As they approach the commissure, the bundles of fibers containing fine and fairly thick argyrophilic fibers are intertwined. Strong bundles and isolated newly formed fibers which form the plexus are seen within the commissure (Fig. 3b). The latter can be traced up to the intestinal wall. An accumulation of neuroblasts is seen along the route of the neural fibers growing into the intestine. They have a round nucleus surrounded by a small rim of cytoplasm. The accumulation of ganglionic cells, numbering two to five, are seen at the base of the commissure near the urinary bladder. There are nodes in the center of the commissure which contain cells of varying maturity and size, including neuroblasts. The pericellular apparatus is clearly visible on some cells. The nodes in the center of the commissure are surrounded as a rule by newly formed vessels; some of the nodes have a capsule. Isolated

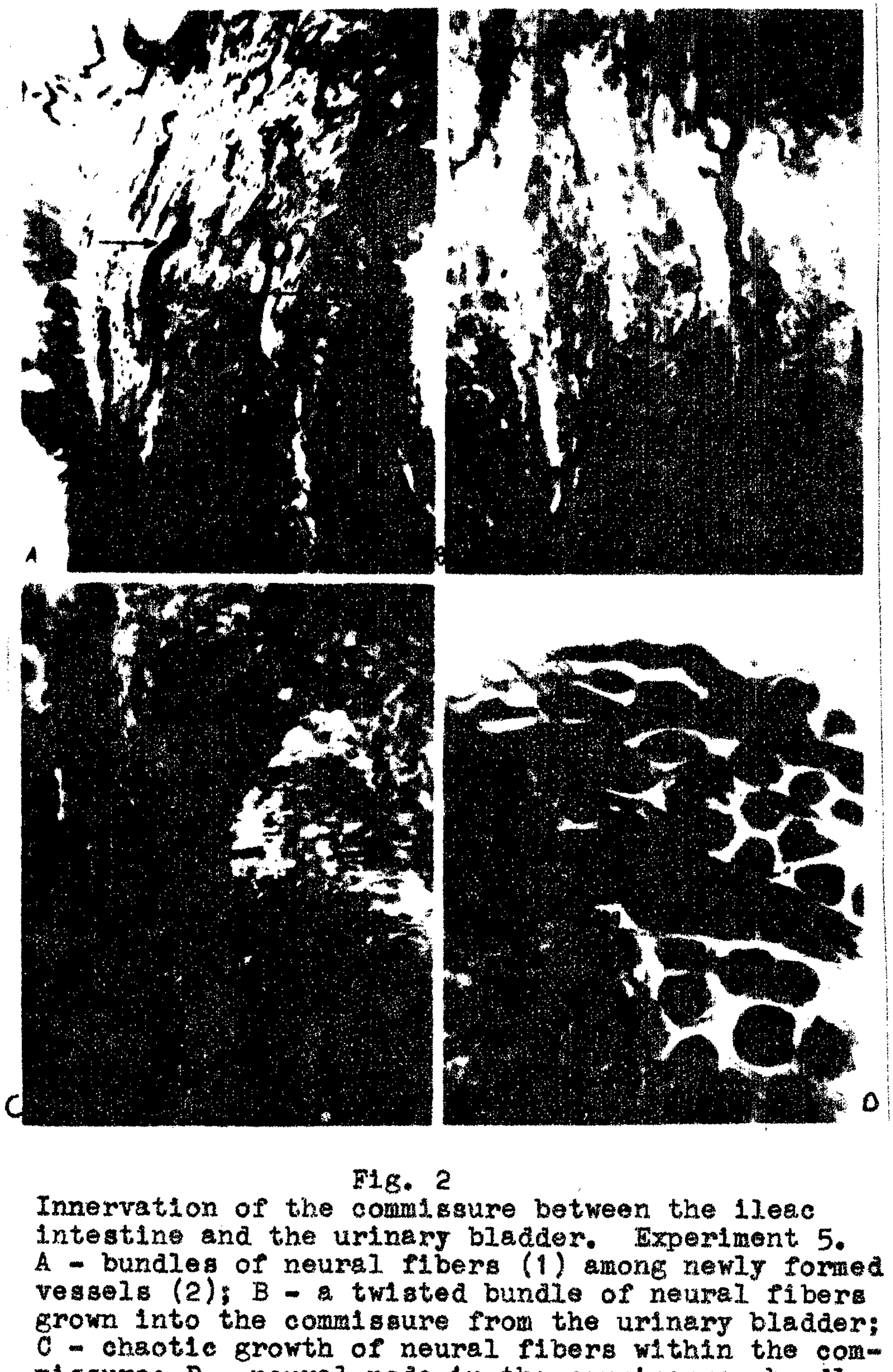

Fig. 2

Innervation of the commissure between the ileac intestine and the urinary bladder. Experiment 5. A - bundles of neural fibers (1) among newly formed vessels (2); B - a twisted bundle of neural fibers grown into the commissure from the urinary bladder; C - chaotic growth of neural fibers within the commissure; D - neural node in the commissure; bundles of neural fibers pass through the body of the node; growth-bulbs are seen. Obj. 8, circumference 10, Microphoto. Rasskazova method.

Fig. 3
Neural fibers in the commissure between the ileac intestine and the urinary bladder. Experiment 13. A - bundles of regenerating neural fibers in the muscular band which participates in the formation of the commissure. Microphoto, obj. 8, circumf. 10. Bil'shovskiy -Gross method. B - bundles of neural fibers in the commissure. Obj. 43, circumf. 10. Bil'shovskiy - Cross method.

growth-bulbs are encountered in the bundles of the neural fibers.

It was stated above that all connections of the urinary bladder, vascular as well as neural, had been eliminated in the present series of experiments. Nevertheless the wall of the urinary bladder appeared pink in the commissure area; hence, we assume that the newly formed vessels participated in the blood supply of the urinary bladder. Histological observation fully corroborated this supposition. Figure 4 shows a section of the commissure between the urinary bladder and the ileum (observation period - 164 days). This figure shows numerous tortuous vessels formed in the commissure which penetrate its body in passing "transit-like" from one organ to another.

Fig. 4
Numerous newly formed blood vessels in the commissure between the ileum and the urinary bladder. Experiment 13. Kampos method with additional staining with hematoxylin-eosin. Magnification 240, microphoto.

During the experiments, an idea came up that the effects obtained by the distention of the samll intestine. In this connection, a control experiment was carried out (Experiment 15) in which, according to the accepted method under conditions of the experiment, a section of the ileum was sutured to the posterior wall of

the urinary bladder. The bladder was then separated from all other connections. A distention of the bladder with 100 to 300 ml. of air for one minute did not caused any change in respiration or blood pressure. The intestinal mesenter was not stretched either in this experiment or in any of the above tests. On the basis of the control, we assume that the effects on the respiration and blood pressure which had been mentioned earlier do not result from the distention of the sutured section of the ileac intestine.

The same fact is supported by other observations. In two cases (experiments 13 and 14) a 10-percent formalin solution was introduced into the commissure after the appearance of new pathways in the urinary bladder had been established. Following this manipulation, distention of the urinary bladder did not cause any change in the blood pressure or respiration (Fig. 5).

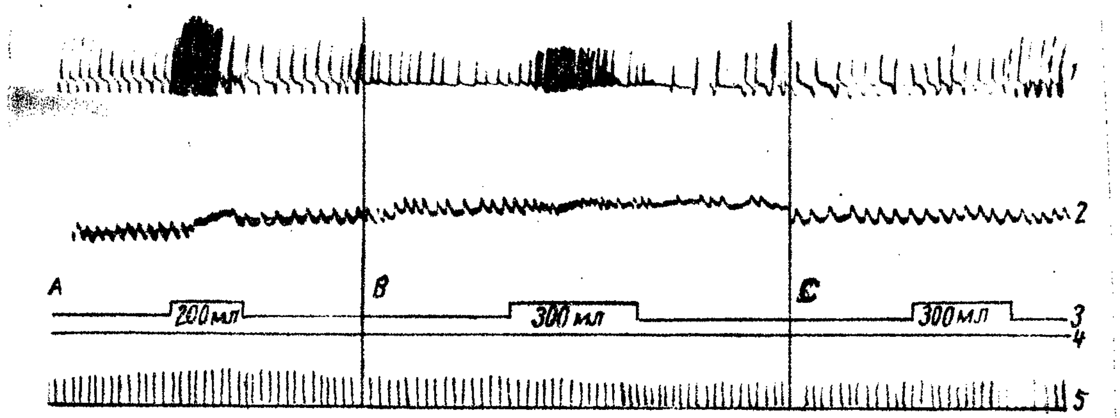

Fig. 5

Effect of urinary bladder distention, by means of a balloon, on blood pressure in the carotid artery and respiration. Experiment 13.
A - distention of the urinary bladder in the control; B - distention of the bladder after the elimination of all its connections with the exception of the newly formed one; C - distention of bladder following the introduction of formalin in the commissure between the ileum and the urinary bladder. 1 - respiration; 2 - blood pressure in the carotid artery; 3 - marking the bladder distention; 4 - zero line of blood pressure; 5 - markimg time -- five seconds.

Thus, there is no reason to doubt that neural impulses, originating upon stimulation of the urinary bladder, are conducted along neural fibers elicited in the commissure.

Experiments were conducted on three dogs by suturing the jejunal intestine to the posterior wall of the urinary bladder. Length of observation -- 70, 87, and 124 days. In contrast to the previous series, the continuity of the serous membrane of the contacting organs was not disrupted; these surfaces were lubricated with alcohol before suturing.

In experiment 18a (length of observation 70 days) during the control tests in which the urinary bladder was distended and (150 ml., 45 sec.) all its connections retained, a phase reaction of the blood pressure with predominance of the depresser phase was noted along with rarer and more intense respiration (Fig. 6a). Following the elimination of all connections of the urinary bladder, except the newly formed one, administration of 150 ml. of air for 45 seconds also causes changes in blood pressure and respiration. These phenomena are less pronounced than in the control tests (Fig. 6b).

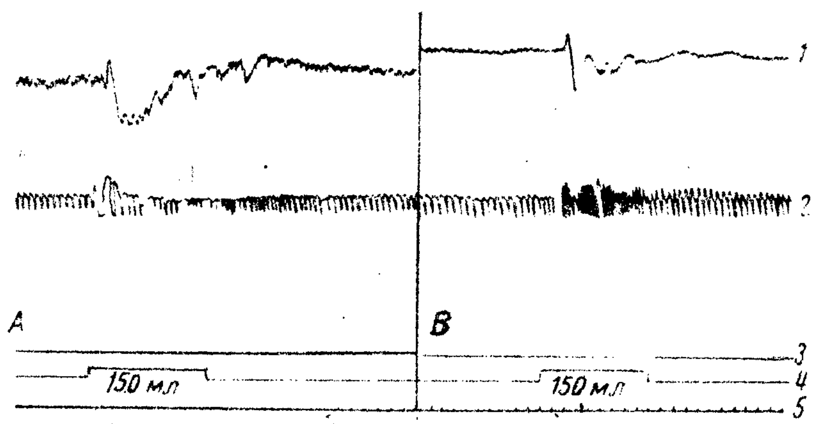

Fig. 6
Effect of the distention of the urinary bladder by a balloon on blood pressure in the carotid artery and respiration. Experiment 18a.
A - distention of the urinary bladder in the control;
B - distention of bladder following elimination of all connections except the newly formed one.
1 - blood pressure in the carotid artery; 2 - respiration; 3 - zero line of blood pressure;
4 - indication of distention of the urinary bladder;
5 - designation of time, five seconds.

Morphological investigation showed that there are, in the commissure, blood vessels and neural bundles consisting of darkly impregnated neural fibers (Fig. 7a). A large number of neural fibers was detected in the commissure also in other cases. For instance, in experiment 14a (length of observation 87 days) newly formed blood vessels and neural fibers were detected in the commissure which had formed between the urinary bladder and the lower intestine.

The neural fibers are located along the vessels as well as between the connective tissue elements of the commissure. Very fine branching of neural fibers was created on the wall of some vessels (Fig. 7b).

Thus, upon suturing the jejunal intestine to the posterior wall of the urinary bladder, new pathways are also formed.

Fig. 7
Neural fibers in the commissure between the intestine and the urinary bladder.
A - branching of the nerves in the commissure. Experiment 18a; B - fine neural fibers on the wall of newly formed vessels. Experiment 14a. Campos method. Obj. 43, circumf. 15.

The possibility was also tested of forming new sensory pathways in the urinary bladder by suturing a part of the caudal wall of the large intestine to it. Experiments were conducted on four dogs (length of observation - 56, 80, and 158 days). In all cases prior to suturing, multiple incisions were made on the serous membrane of the urinary bladder and large intestine.

The following results were obtained.

In experiment 2a a dog was kept under observation for 158 days. Distention of the bladder (100 ml., 45 sec.), which retained its vascular and neural connections, caused a considerable reduction of blood pressure and a marked enhancement and acceleration of respiration. After the air in the balloon had been reduced, the abovementioned changes in blood pressure and respiration were still more pronounced and lasted for 110 seconds. Movement of head and extremities were noted (Fig. 8a).

After all connections of the urinary bladder were eliminated but while retaining its connection with the large intestine via the commissure -- the bladder distention (100 ml., 45 sec.) caused a reduction of blood pressure and an enhancement and acceleration of respiration (Fig. 8b). The latter lasted 25 seconds following removal of the air from the balloon. Movements of the head were noted.

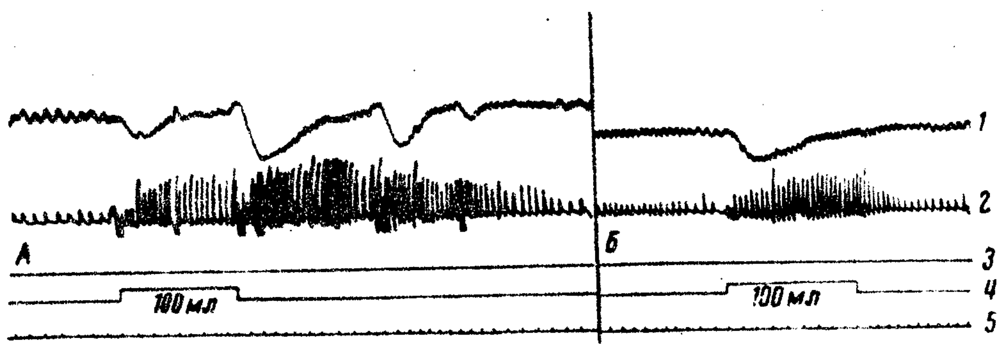

Fig. 8
Effect of balloon distention of the urinary bladder on the blood pressure in the carotid artery and respiration. Experiment 2a.
A - distention of the urinary bladder in the control; B - distention of bladder following elimination of all connections with the exception of the newly formed one. Markings are the same as on Fig. 6.

From the above experiment, one can assume that upon suturing the caudal part of the large intestine to the posterior wall of the urinary bladder new afferent pathways of the urinary bladder appear. Histological studies of the commissure corroborate this assumption. In the latter, parallel with nemerous vessels, bundles and separate neural fibers emerge.

This experiment does not permit the determination of the pathways along which impulses flow into the central nervous system. This problem is subject to further special study. But there is already a possibility of the present stage of investigation of proposing a hypothesis on the nature of these pathways. One can assume, in particular, that under conditions of our experiment, the impulses may spread along the pelvic nerves as well as along those located at a higher level. Two other experiments support this reasoning (1 and 3a).

We shall cite some data from experiment 3a. The wall of the caudal section of the large intestine is sutured to the posterior wall of the urinary bladder (length of observation -- 80 days). On opening the abdominal activity a commissure between the large intestine and the bladder is noted. When all connections are retained, the distention of the urinary bladder (100 ml. of air, one minute) caused only a slight change in blood pressure and respiration. Bladder distention of 200 and 300 ml. of air led to more pronounced changes of blood pressure and respiration (Fig. 9a). In subsequent tests, in order to clarify the problem of formation of new pathways and the spreading of impulses along them, all connections of the urinary bladder were eliminated and the large intestine below the commissure was cut off. Under these conditions the participation of pelvic nerves and pelvic plexus in the innervation of the large intestine was excluded. It was then demonstrated that distention of the urinary bladder with large quantities of air (500 ml., one minute) exert an insignificant effect (Fig. 9b).

In other words, one can assume that the newly formed pathways are basically formed by pelvic nerves. Morphological study of the commissure reveals the emergence of new pathways. We can thus detect nemerous newly formed blood vessels of various sizes; between these vessels, and quite frequently along their path, a large number of fine neural bundles as well as solitary neural fibers are detected (Fig. 10a). Together with the latter there are neural nodes present in the commissure. The largest of them (Fig. 10b) is surrounded by a capsule and consists of numerous neural cells; a large bundle of neural fibers

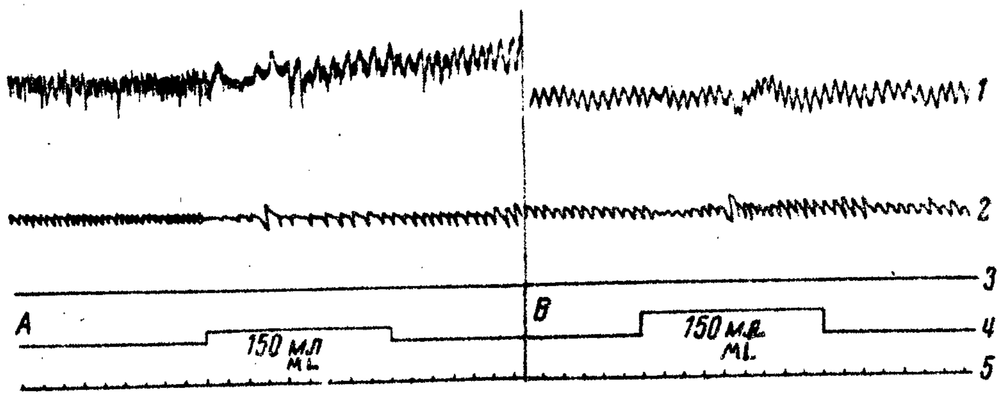

Fig. 9
Effect of distention of the urinary bladder with a balloon on the blood pressure in the carotid artery and respiration. Experiment 3a.
A - distention of bladder in control; B - distention of the bladder following elimination of all its connections, with the exception of the newly formed one; the large intestine below the commissure is cut off. Markings -- the same as in Fig. 6

is connected with the node; some of them branch out among the nodal cells. Pronounced bundles of neural fibers in the commissure were also detected in experiment 4a. As seen on Fig. 10b, the commissure has an appearance of a narrow band. Two bundles are seen within its mass which consist of fine neural fibers located longitudinally along the path of the connective tissue elements of the commissure.

The data of this series of experiments show that new neural connections appear during the formation of a commissure between the urinary bladder and the large intestine. There are reasons to believe that pelvic nerves participate chiefly in their formation. These experiments also showed that, when the continuity of the serous membrane where the urinary bladder contacts the large intestine in disrupted, neural fibers as well as neural nodes are formed.

To study the possibility of forming new pathways for all organs of the lesser pelvis, we conducted two series of experiments wherein sections of the jejunum and ileac intestines were sutured to the caudal section of the large intestine; the contacting surfaces were lubricated with alcohol. Upon suturing the ileac to the large intestine we were able to note, as in previous instances, formation of commissures.

Fig. 10
Innervation of the commissure between the rectum and the urinary bladder.
A - newly formed blood vessels and neural fibers; B - neural node in the commissure. Experiment 3a, obj. 43, circumf. 15; C - longitudinal neural bundles in the commissure. Experiment 4a. Kampos method. Obj. 8, circumf. 10, microphoto.

Stimulation of the caudal end of the large intestine caused the appearance of new afferent pathways passing through the commissure. This relationship can be illustrated by the following experiments.

Experiment 10a. Dog, male, weight - 21 kg. The ileac intestine is sutured to the ventral caudal section of the large intestine. After 153 days a precise experiment was carried out. Distention of the large intestine in the area of the commissure (100 ml. of air for 45 seconds) leads to an increase of blood pressure, slowing-up, and -- later -- intensification of respiration. The section of the large intestine connected through a commissure with the small intestine was isolated, i.e., was ligated with a silk ligature proximally and distally from the sutured area, and separated from the rest of the large intestine. The mesentery of this isolated area was cut. Thus, a completely isolated area of the large intestine

was created which remained connected with the small intestine through a commissure only. When this area of the intestine was distended (150 ml. of air, 45 sec.), a lowering of blood pressure, a diminished amplitude of its fluctuations, as well as intensification and acceleration of respiration were noted; movements of the head were observed. Morphological examination of the commissure showed newly formed vessles and bundles of neural fibers. The latter could be traced along the entire length, from the wall of the small intestine to the wall of the large one. The neural fibers were thin, and their outline - regular.

Of considerable interest is another case in this series (Experiment 21a). The wall of the ileum was sutured to the large intestine. One hundred and seventeen days later, another precise experiment was carried out. Distention of the large intestine (100 ml. air, 45 sec.), while all its connections were preserved caused first a pressor effect, followed later by a depressor effect on blood pressure, and a weakening followed later by intensification of respiration (Fig. 11a). Distention of the isolated area of the large intestine at the seat of its commissure with the small intestine (100 ml. air, 45 sec.) produced a prenounced depressor effect, and marked weakening followed by acceleration of respiration (Fig. 11b)

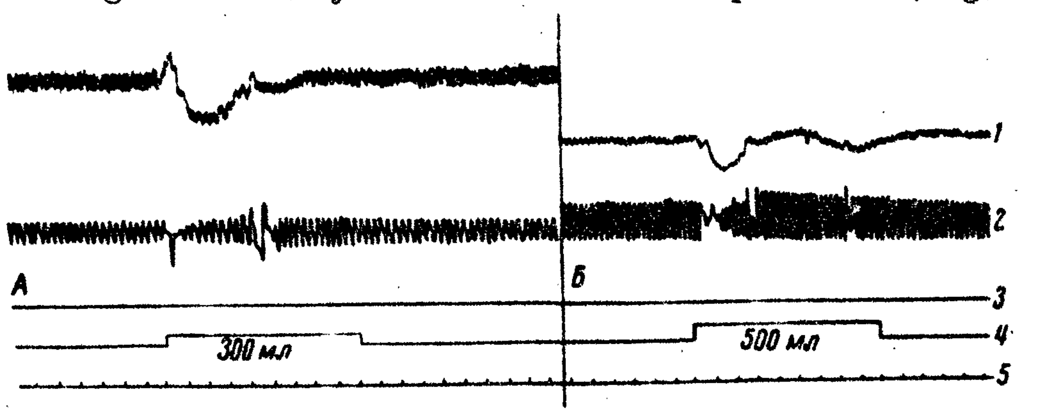

Fig. 11
Effect of balloon-distention of the caudal part of the large intestine on the blood pressure in the carotid artery and or respiration. Experiment 21a.
A - distention of the large intestine in control;
B - distention of the large intestine following elimination of all its connections except the newly formed one. 1 - blood pressure in the carotid artery; 2 - respiration; 3 - zero line of blood pressure; 4 - marking the distention of the large intestine; 5 - marking of the time - five seconds.

This case is interesting because within 50 days after the suturing the dog gave birth to five live, healthy puppies. In other words, the operation not only had no effect on the course of pregnancy but also did not prevent the birth of healthy, mature puppies. It is necessary to note that pregnancy and labor did not prevent the formation of a commissure; the neural elements which had developed in the latter proved capable of transferring the stimuli from the caudal end of the large intestine to those sections of the central nervous system situated at a higher level.

In the subsequent series of experiments in which the small intestine was sutured to the ventral caudal portion of the large intestine, the same operations were performed as in previous series. Commissures were noted between the sutured parts of the small and large intestines in all experiments. In the special experiment with the distention of the caudal segment of the large intestine when all connections were retained, also during subsequent elimination of these connections leaving only one commissure between the sutured parts of the intestines pronounced changes of blood pressure and respiration were observed. Movements of the head and extremities were noted. Morphological examination of the commissure showed a large number of blood vessels, neural bundles and separate fibers.

As confirmation of the above, we cite the results of observations in experiments 5a, 6a, 7a.

Experiment 6a. The small intestine is sutured to the caudal part of the large intestine. A special experiment was performed 124 days later. Distention of the large intestine in the commissure area (100 ml. air, 45 sec.), while all its connections are preserved causes changes of blood pressure (phasic period) and intensification and acceleration of respiration (Fig. 12a). These changes of blood pressure and respiration continue also after the cessation of stimulation and revert to normal only after 20 to 30 seconds. Besides, movements of the head and rear extremities are observed. We then performed a consecutive separation of the sutured segment of the large intestine. First, the rectum was separated and the mesentery, together with the blood vessels, was cut off. In this instance, the distention of the large intestine in the commissure area (100 ml. of air, 45 sec.) causes a reduction of blood pressure and some change in respiration.

Finally, the segment of the large intestine connected via the commissure with the small intestine is fully isolated. Stimulation of the isolated segment of the large intestine (150 ml. of air, 45 sec)

causes change in blood pressure and some intensification followed by slowing of respiration (Fig. 12b). Analogous data were obtained in experiments 5a and 7a. Length of observation was respectively 118 and 89 days.

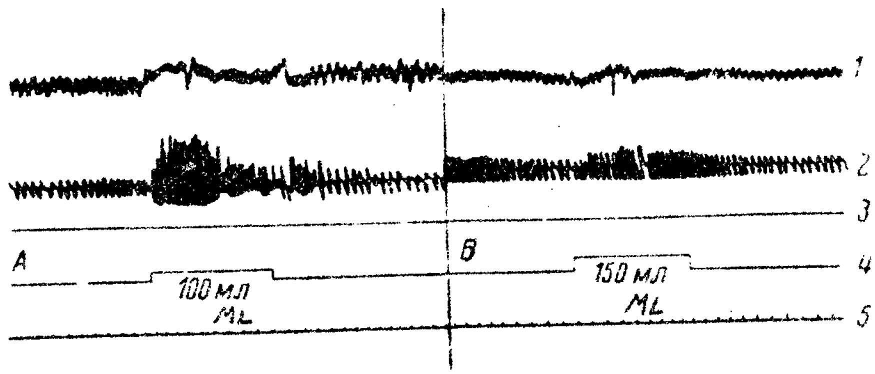

Fig. 12

Effect of distention, of the caudal part of the large intestine by a balloon, on blood pressure in the carotid artery and respiration. Experiment 6a.
A - distention of the large intestine in control;
B - distention of the large intestine after elimination of all connections except the newly formed one. Designations the same as on Fig. 11.

Histological examination of the commissures in these experiments showed a large number of blood vessels, neural bundles, and separate fibers (Fig. 13a, b, and c). The neural fibers have a twisted pattern, their outlines are unchanged; the thickness of the fibers is uneven. The neural bundles and fibers are grouped along the path of the blood vessels or beyond them.

These results support the belief that upon suturing the small intestine with the urinary bladder or large intestine, or suturing the urinary bladder with the large intestine, collateral afferent connections of pelvic organs with the central nervous system emerged.

Similar connections can be obtained also under systematic conditions. In one series of experiments (four dogs) an anastomosis was formed between the external cutaneous femoral nerve and the hypogastric nerves. Both nerves were cut and the central end of the external cutaneous femoral nerve was sutured to the peripheral segment of both gastric nerves in the area of the caudal

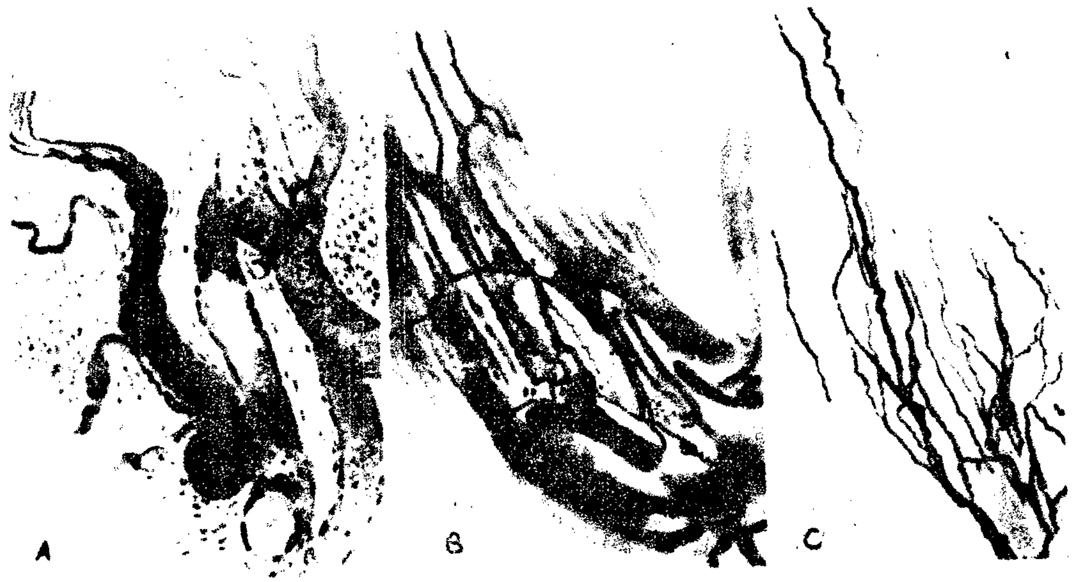

Fig. 13
Innervation of commissures between the large and small intestines.
A - vessels and a neural bundle in a commissure between the caudal segment of the descending part of the large intestine and the ileum. Experiment 21a; B - vessels and nerves in a commissure between the caudal segment of the descending part of the large and small intestines. Experiment 5a; C - neural bundles and separate neural fibers in a commissure between the caudal segment of the large intestine and the small intestine. Experiment 7a. Campos method. Obj. 43, circumf. 10.

mesenteric node. After various periods (57, 112, 148, and 252 days), a study was made of the structure and function of the created anastomosis.

In experiments 1 and 7 the regeneration process of the fibers of the external cutaneous femoral nerve and their distribution in the hypogastric nerves was studied. It was established in both cases that the central end of the external cutaneous femoral nerve split fan-like in the area of the neuroma. The regenerating axons of this nerve pass through the scar in separate parallel bundles and grow into the hypogastric nerves (Fig. 14a). Young nerve fibers and dilated twisted blood vessels are seen in the epineurium of the hypogastric nerves. Some regenerating fibers form complex curls and pass

Fig. 14
Suturing of the external cutaneous femoral nerve with the hypogastric nerves. Ingrowing of neural fibers of the external cutaneous femoral nerve into hypogastric nerves. A - bundles of regenerating neural fibers grown into the hypogastric nerve of a dog after suturing the external cutaneous femoral nerve with the peripheral segment of the hypogastric nerve. Experiment 7. Obj. 40, circumf. 2, microphoto. B - bulb-like bulge on a regenerating fiber in the hypogastric nerve. Experiment 7. C - breaking up of hypogratric nerve fibers following a repeated separation of the external cutaneous femoral nerve of a dog. Experiment 11. D - breaking up of a bundle of neural fibers in the pelvic plexus of a dog following a repeated separation of the external cutaneous nerve. Experiment 11. Bil'shovskiy method. Cross, obj. 40 circumf. 10, microphoto.

into the opposite direction. Growth bubls are noted at the ends of the regenerating fibers (Fig. 14b). The newly formed fibers issue collaterals which terminate simultaneously in several bulb-like bulges. Regenerating neural fibers are encountered which form Perroncite spirals. On the wall of blood vessels passing through the hypogastric nerves, endings of the collaterals of young neural fibers are detected in the hypogastric nerves up to the pelvic node.

Experiment 11. An anastomosis was produced in a dog between the central (abdominal) end of the left external cutaneous femoral nerve and the distal segments of both hypogastric nerves which had been separated in the area of the caudal mesenteric node. Two hundred and fifty-two days later a second operation was performed in which the external cutaneous femoral nerve was separated centrally away from the place of its suturing with the hypogastric nerves.

Histological examination of the nerves was made starting with the place of its separation and extending to the urinary bladder, consecutively, and by segments.

A massive breaking up of neural fibers is observed in the external cutaneous nerve of the femur somewhat distally to the place of separation. Some fibers are of irregular outlines and vacuolized. Some isolated fine fibers are intact. Such a picture is seen along the entire length of the hypogastric nerves; the majority of neural fibers is in the state of disintegration into fragments of various sizes and shapes (Fig. 14c). The pelvic plexus contains a considerable number of degenerated neural fibers in the form of ovoids containing fragments of granular, disintegrated axis cylinders (Fig. 14d). Altered neural fibers are seen in the urinary bladder wall and in the ureteral orifices.

This series of experiments, involving anastomosis of the external cutaneous femoral nerve with the hypogastric nerves, domonstrates that, upon formation of heterogeneous links of this type, the fibers of the external cutaneous femoral nerve regenerate and grow through, up to the wall of the urinary bladder. Therefore, a possibility has been established of forming new sensory pathways in the internal organs by means of afferent fibers of somatic nerves situated at a higher level. Physiological studies in this direction produced encouraging results.

The above-factual data demonstrate that in all types of the union of various sections of the intestinal tube with the urinary bladder, as well as of the small intestine with the distal large intestine, new afferent pathways appear in

the urinary bladder and large intestine.

It seems to us that these pathways are formed by fibers of the vague and splanchnic nerves, as well as the pelvic nerves which pass into the intestinal wall; these fibers, when the organs are sutured together, regenerate and grow into the commissure. On the other hand, growing of neural fibers into the commissure from the urinary bladder wall has been observed. If we consider the statement of V. N. Blumkin on the transit-growth of nerves and formation of heterogenous nerve endings in the sutured organs, we must admit that the nerves growing from the urinary bladder into the commissure also participate in the formation of new neural pathways. In all experiments, definite bundles and separate neural fibers were detected in various quantities in the commissures. These fibers have regular outlines. After lengthy observations, fairly large, intensively impregnated neural fibers could be detected against a background of numerous fine fibers and bundles. By comparing pictures observed in normal embryogenesis, one may assume that the above-mentioned larger fibers are of medullary origin.

There is no doubt that the neural fibers observed in the commissures are newly formed. The growth picture of these fibers as well as the neuromas observed in the commissure support this view.

The position and path of the nerves in the commissure depends on the peculiarities of its structure. A haphazard growth of neural fibers is seen more frequently, a characteristic of regenerating fibers in a neural scar. When longitudinal connective tissue structures predominate in the commissure, the neural fibers imitate the path of these structures. Pathologically changed neural fibers were very rarely observed. At times, argyrophilia and swelling of isolated neural fibers were noted.

Morphological study of the commissures enabled us to make certain observations not mentioned in the literature. In those experiments, in particular, where the serous membrane had been removed from the contacting surfaces of the sutured organs or in instances where its continuity had been disrupted by numerous incisions, neural nodes and isolated neural cells in the formed commissures have been detected. The point should be stressed here that neural cells were not found in the commissure when the serous cover had been retained, i.e., in cases where the serous membrane had been lubricated with alcohol before suturing the organs. One can assume that, when the continuity of the serous membrane is disrupted, causing traction from the forming commissure, the

neural nodes are transferred from the wall of the organs into the commissure. The prolonged presence of the described nodes in the commissures does not visibly effect their structure.

Newly formed vessels are detected without exception in all commissures formed between the sutured organs. The data in our possession attest to the fact that these vessels function and supply to some extent the organs from which all connections had been eliminated in the experiment. These data coincide with the observations of T. N. Gorbasheva (1958), A. N. Skobunova (1957) etc., who think that the blood vessels growing from one organ to another are capable of compensating the basic vascular trunk lines of this organ. As already mentioned, neural fibers grow into the commissure along the path of these vessels.

It is known that organs are very often sutured in the clinic for various reasons (suturing of orifices, ileocystoplasty, esophageal plastics). In analysis of performed operations of this type, only the results of direct suturing are considered. But the significance of the newly formed neural pathways is not subjected to analysis. As an example, we can cite ileocystoplasty and colocystoplasty employed by native and foreign scientists (S. D. Goligorskiy, 1957, 1958; Ye. P. Tsvetov, 1958, 1959; Bitker, 1958; Kuss, 1958, etc.). In particular, Bitker reports a case in which a plastic operation of the urinary bladder was performed in a man by means of a segment of the ileum; in this instance, paraglegia had originated as the result of a spine fracture at the level of D_{12} -- L_1. The author notes the restoration of the urinary bladder function. The question of the significance of new neural connections originating in this process has not even been raised. The same omission can be found in the works of a number of other researchers.

We feel that the results of our investigations will be of significance also in the analysis of observations made by physiologists. The latter widely employ fistulas on hollow organs (gallbladder, stomach, etc.). In these cases the walls of these organs unite, during their growth, with the anterior abdominal wall. And, as is known, such union of organs is accompanied by the penetration of neural fibers into the commissure. The physiologists, however, do not take this fact into account and do not bring out the importance of the newly formed neural connections in the results obtained by them.

The significance of newly formed pathways must undergo further study.

Conclusions

1. In suturing various areas of the small or large intestines to the urinary bladder, also in suturing the small intestine to the large one, new afferent neural pathways are formed connecting the organs of the true pelvis with the central nervous system.

2. The regenerating bundles of neural fibers growing from the sutured organs into the commissure are the morphological substrate of the newly formed pathways.

3. Upon the removal of the serous membrane from the areas of sutured organs, neural nodes and isolated neural cells appear in the commissures.

4. In experiments with the formation of "anastomoses" between the central segment of the separated external cutaneous femoral nerve and the peripheral segments of the hypogastric nerves, an extension of the regenerating fibers of the external femoral nerve up to the orifices of the ureters takes place. In other words, formation of new afferent pathways of the urinary bladder is possible in anastomoses of this type.

5. The obtained results represent the experimental basis for the development of methods of restoration of sensory capacity of the organs of the true pelvis when the spinal cord in the lumbo-sacral region is severed.

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